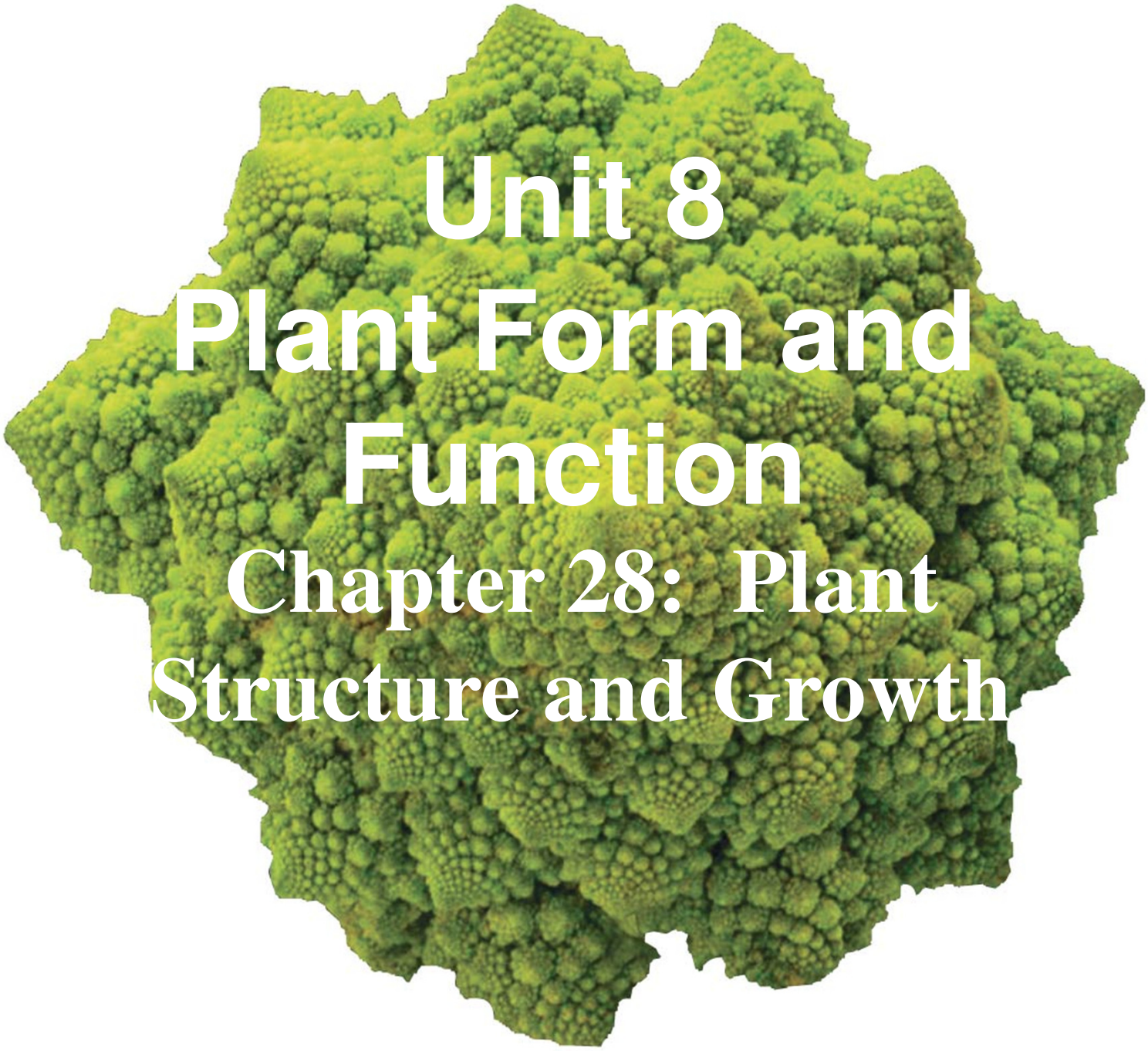


Unit 8
Plant Form and Function
Chapter 28: Plant Structure and Growth

Overview

- The development of plants depends on the environment and is highly adaptive
  - Plants respond to environment by altering their growth
- Angiosperms are primary producers and are important in agriculture
- Taxonomists split the angiosperms into two major clades:
  - Monocots-One cotyledon (seed leaf)
    - Grasses (wheat, corn, rice), orchids, bamboo, palms, lilies
  - Eudicots-Two cotyledons
    - Beans, sunflowers, maples, oaks

Figure 28.2a

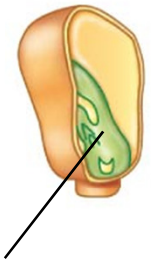
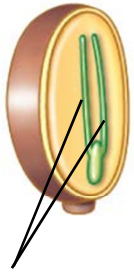
	Monocots	Eudicots
Embryos	 One cotyledon	 Two cotyledons
Leaf venation	 Veins usually parallel	 Veins usually netlike

Figure 28.2b

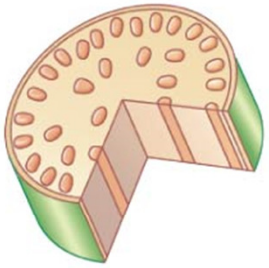
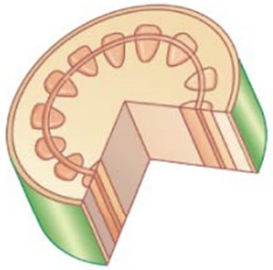
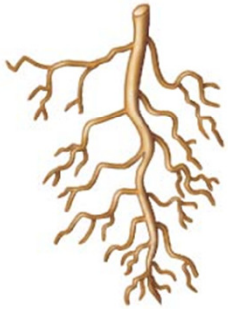
	Monocots	Eudicots
Stems	 **Vascular tissue scattered**	 **Vascular tissue usually arranged in ring**
Roots	 **Root system usually fibrous (no main root)**	 **Taproot (main root) usually present**

Figure 28.2c

	Monocots	Eudicots
Pollen	 Pollen grain with one opening	 Pollen grain with three openings
Flowers	 Floral organs usually in multiples of three	 Floral organs usually in multiples of four or five

Concept 28.1: Plants have a hierarchical organization consisting of organs, tissues, and cells

- Plants have organs composed of different tissues, which in turn are composed of different cell types
- An **organ** consists of several types of tissues that together carry out particular functions
  - Roots, stems, leaves
- A **tissue** is a group of cells consisting of one or more cell types that together perform a specialized function
  - Dermal, vascular, ground

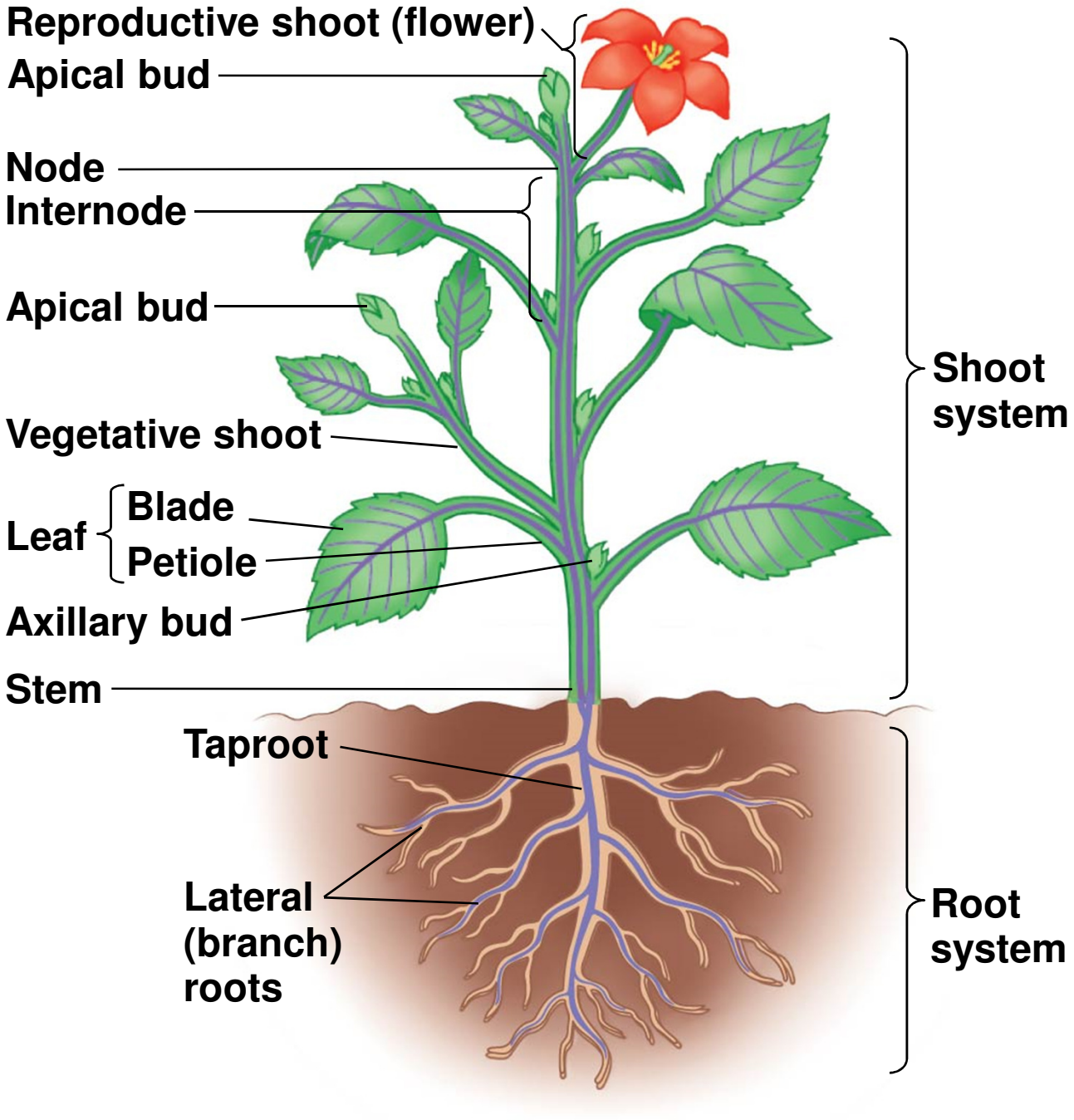
The Three Basic Plant Organs: Roots, Stems, and Leaves

- The basic morphology of vascular plants reflects their evolution as organisms that draw nutrients from below ground and above ground
- Plants take up water and minerals from below ground
- Plants take up CO_2 and light from above ground

- Three basic organs evolved to acquire these resources: roots, stems, and leaves
- The **root system** includes all of the plant's roots
- The **shoot system** includes the stems, leaves, and (in angiosperms) flowers

- Roots rely on sugar produced by photosynthesis in the shoot system
- Shoots rely on water and minerals absorbed by the root system

Figure 28.3


Reproductive shoot (flower)
Apical bud
Node
Internode
Apical bud
Vegetative shoot
Leaf
Blade
Petiole
Axillary bud
Stem
Taproot
Lateral (branch) roots
Shoot system
Root system

Roots

- A **root** is an organ with important functions
  - Anchoring the plant
  - Absorbing minerals and water
  - Storing carbohydrates

- Tall, erect plants with large shoot masses have a *taproot system*, which consists of
  - A **taproot**, the main vertical root
    - Helps prevent plant from toppling
    - Energetically expensive to make, but allows plant to be taller
      - Better access to light
      - Advantage for pollen and see dispersal
  - **Lateral roots** branching off the taproot
    - Absorption role

- Small or trailing plants have a *fibrous root system*, with a mat of thin roots spreading out below soil surface
  - Consists of
    - Adventitious roots that arise from stems
    - Lateral roots that arise from the adventitious roots and form their own lateral roots
  - Good for preventing soil erosion

- In most plants, absorption of water and minerals occurs through the **root hairs**
  - Thin extensions of epidermal cells that increase surface area

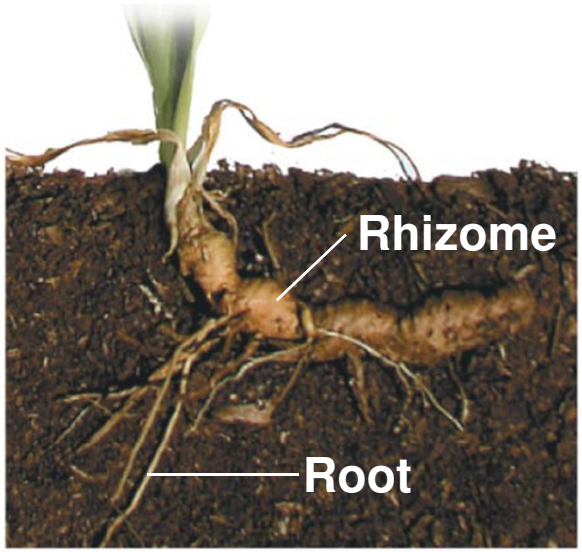
- Most terrestrial plants form mycorrhizal associations, which increase mineral absorption
- Many plants have root adaptations with specialized functions

Stems

- A **stem** is the organ to which leaves are attached
  - Chief function is to elongate and orient shoot in a way that maximizes photosynthesis by leaves
  - Also elevates reproductive structures
  - Consists of
    - An alternating system of **nodes**
      - The points at which leaves are attached
    - **Internodes**
      - The stem segments between nodes

- An **apical bud**, or terminal bud, is located near the shoot tip and causes elongation of a young shoot
- An **axillary bud** is located in the upper angle formed by the leaf and the stem and has the potential to form a lateral branch, thorn, or flower
  - Axillary buds are generally dormant
- Some plants have modified stems with additional functions
  - Rhizomes, bulbs, stolons, tubers

Figure 28.6



Rhizomes

Stolons

Tubers

Leaves

- The **leaf** is the main photosynthetic organ of most vascular plants
- Leaves have other functions including gas exchange, dissipation of heat, and defense
  - Conflicting demands and trade-offs
- Leaves generally consist of a flattened **blade** and a stalk called the **petiole**, which joins the leaf to the stem

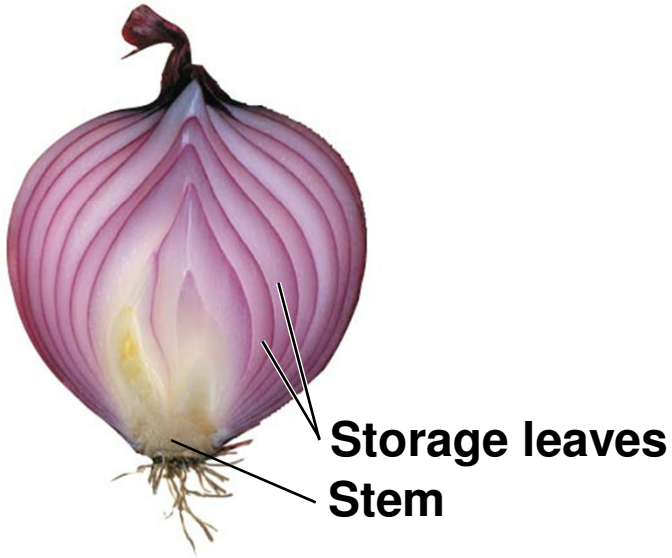
- Monocots and eudicots differ in the arrangement of **veins**, the vascular tissue of leaves
  - Most monocots have parallel veins
  - Most eudicots have branching veins
- Some plant species have evolved modified leaves that serve various functions
  - Support, protection, storage, reproduction

Figure 28.7

Spines

Tendrils

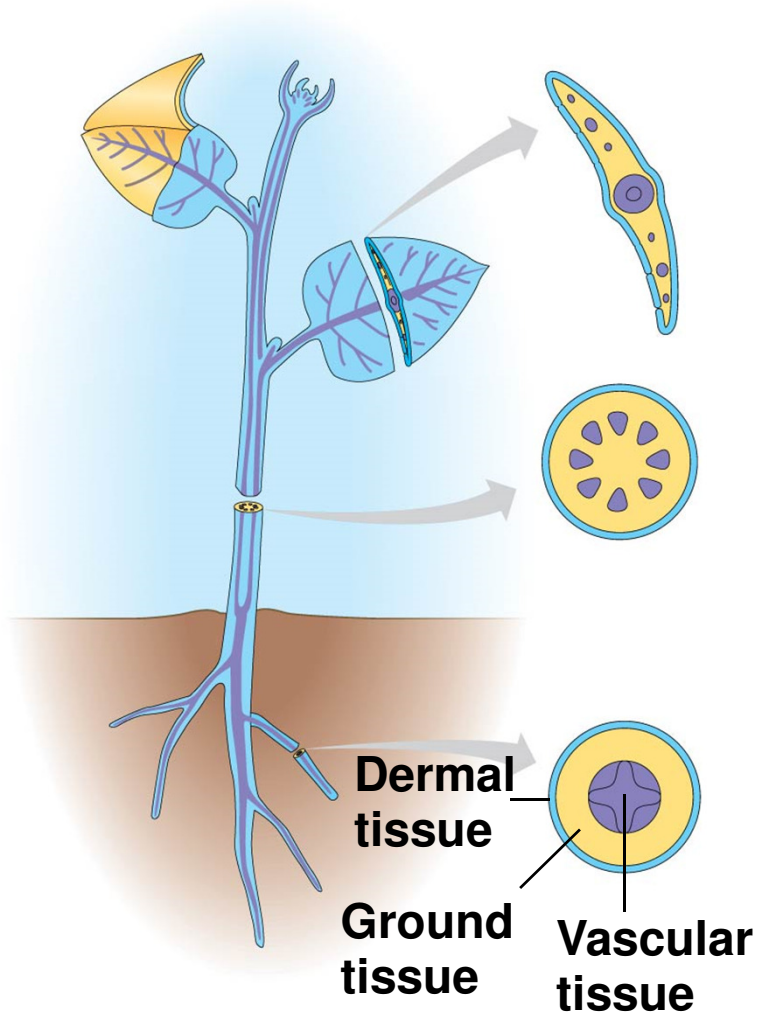
Reproductive leaves



Storage leaves

Dermal, Vascular, and Ground Tissue Systems

- Each plant organ has dermal, vascular, and ground tissues
- Each of these three categories forms a continuous **tissue system**



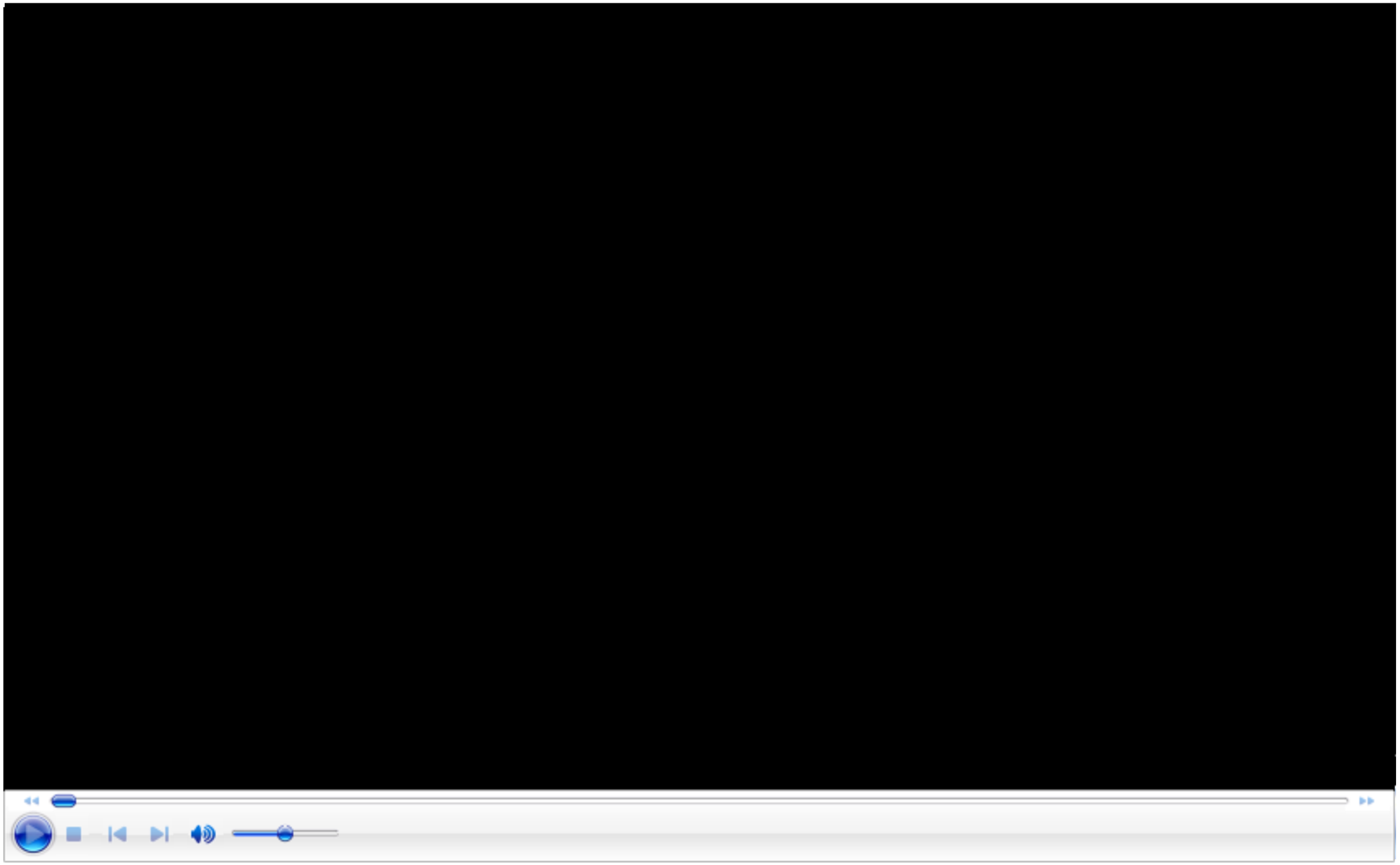
- The **dermal tissue system** is the outer protective covering
  - First line of defense
- In nonwoody plants, the dermal tissue system consists of the **epidermis**
  - A layer of densely packed cells
- In leaves and most stems, a waxy coating called the **cuticle** helps prevent water loss from the epidermis
- In woody plants, protective tissues called **periderm** replace the epidermis in older regions of stems and roots
- *Trichomes* are hair-like outgrowths of the shoot epidermis and can help with insect defense

- The **vascular tissue system** facilitates transport of materials through the plant and provides support
- The two vascular tissues are xylem and phloem
  - **Xylem** conducts water and dissolved minerals upward from roots into the shoots
  - **Phloem** transports sugars from where they are made to where they are needed
- The vascular tissue of a root or stem is collectively called the **stele**

- Tissues that are neither dermal nor vascular are the **ground tissue system**
- Ground tissue internal to the vascular tissue is **pith**
- Ground tissue external to the vascular tissue is **cortex**
- Ground tissue includes cells specialized for photosynthesis, short-distance transport, storage, or support

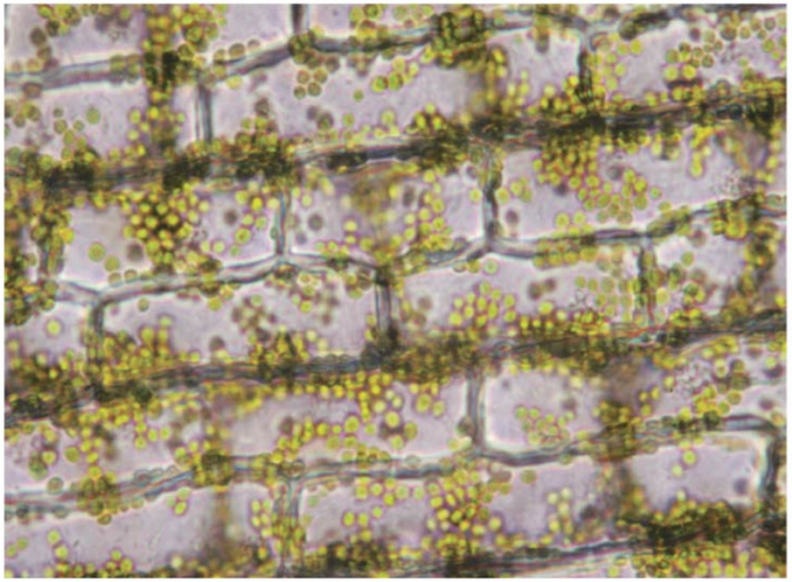
Common Types of Plant Cells

- Plant cells have structural adaptations that make their specific functions possible
- The major types of plant cells are
  - Parenchyma
  - Collenchyma
  - Sclerenchyma
  - Water-conducting cells of the xylem
  - Sugar-conducting cells of the phloem

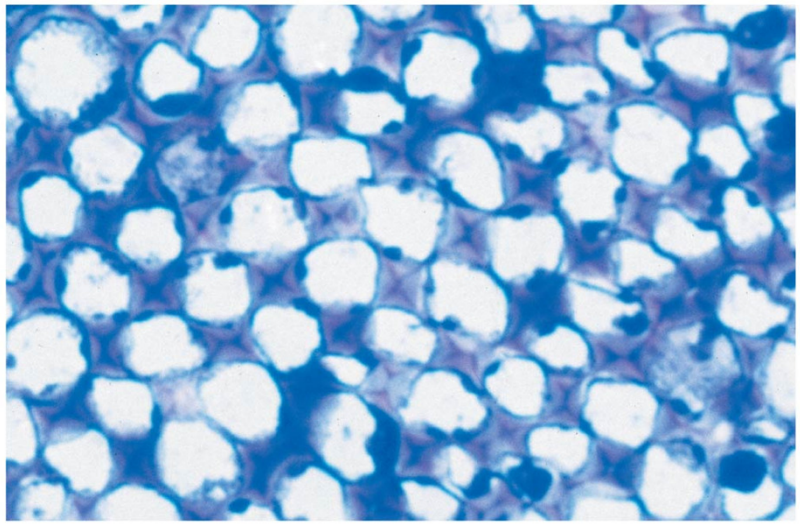


Animation: Tour of a Plant Cell

- **Parenchyma cells**
  - Have thin and flexible primary walls
  - Lack secondary walls
  - Have a large central vacuole
  - Perform the most metabolic functions
  - Retain the ability to divide and differentiate

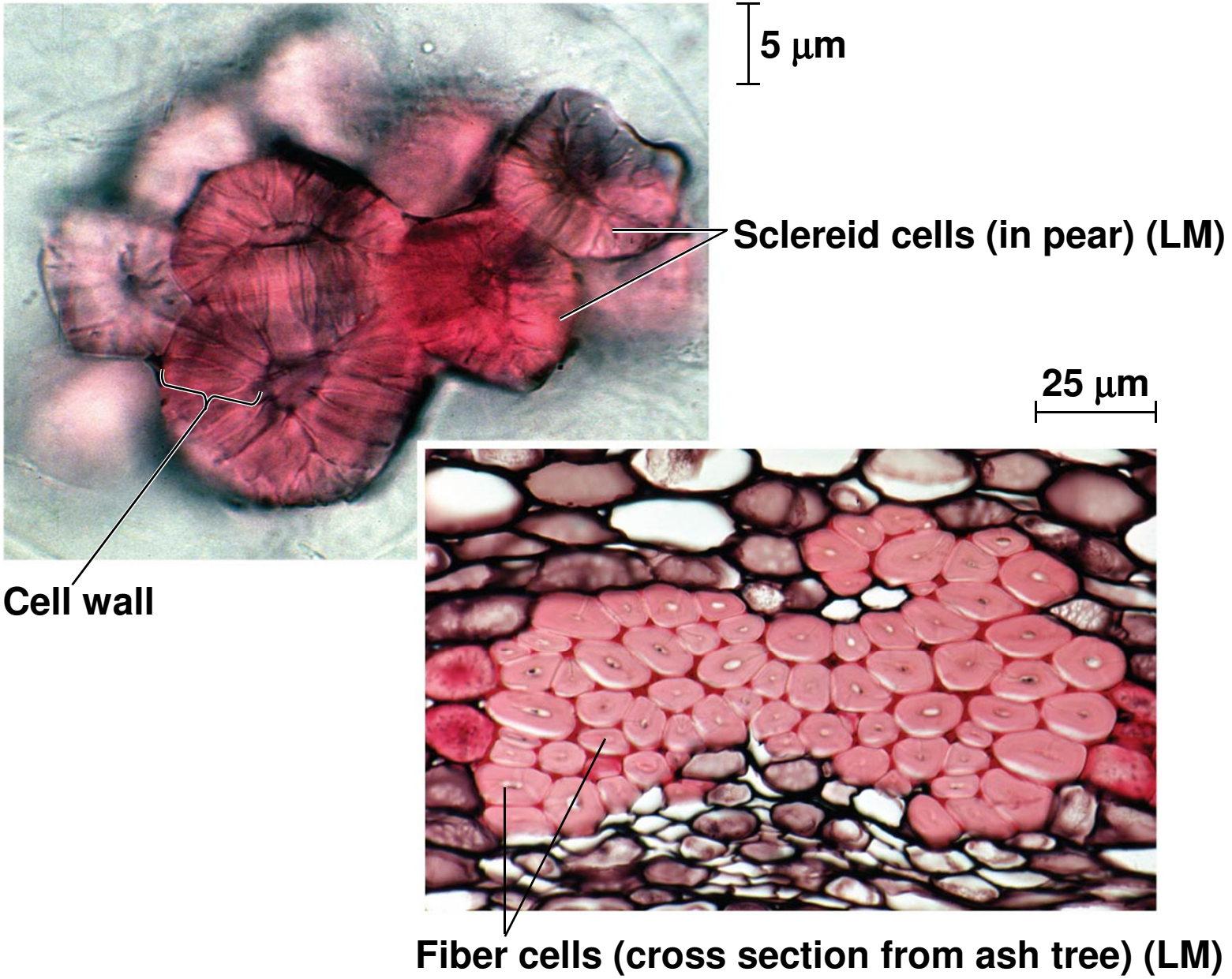


- **Collenchyma cells**
  - Are grouped in strands
  - Help support young parts of the plant shoot
  - Elongated with thicker and uneven cell walls
  - Lack secondary walls
  - Provide flexible support without restraining growth



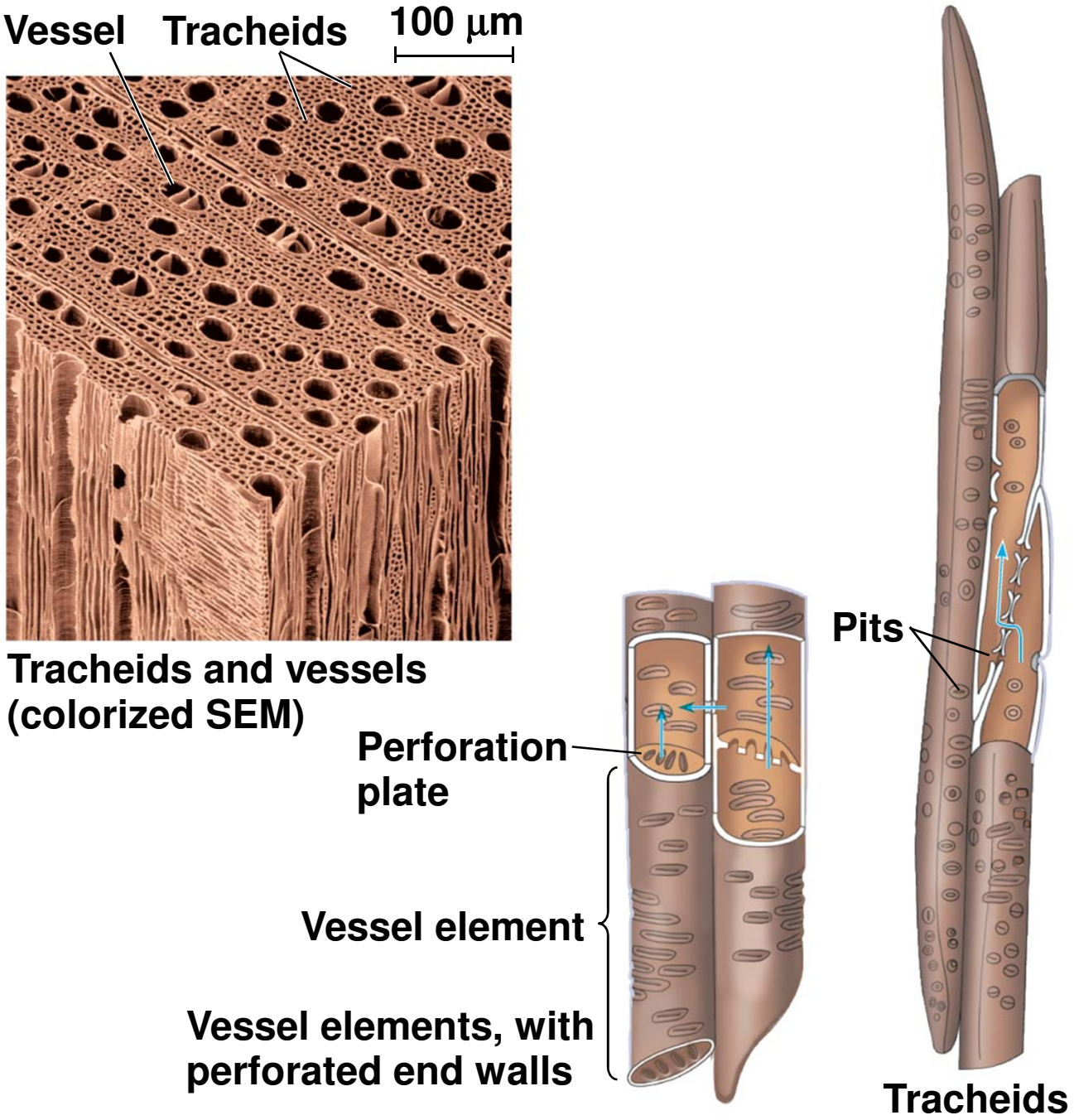
- **Sclerenchyma cells** are specialized for support and strengthening
  - Rigid due to thick secondary walls containing **lignin**, a strengthening polymer
- They are dead at functional maturity
  - Cannot elongate
- There are two types
  - **Sclereids** are short and irregular in shape and have thick, lignified secondary walls
  - **Fibers** are long and slender and grouped in strands

Figure 28.9c


5 µm
Sclereid cells (in pear) (LM)
Cell wall
25 µm
Fiber cells (cross section from ash tree) (LM)

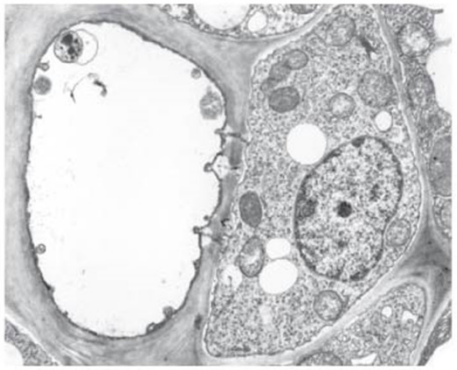
- **Water-conducting cells of the xylem** are dead at functional maturity
- There are two types of water-conducting cells
  - **Tracheids** are long, thin cells with tapered ends that move water through pits
    - Tracheids occur in xylem of all vascular plants
  - **Vessel elements** align end to end to form long micropipes called **vessels**
    - Vessel elements are common to most angiosperms, a few gymnosperms, and a few seedless vascular plants

Figure 28.9d


Vessel
Tracheids
100 µm
Tracheids and vessels (colorized SEM)
Perforation plate
Vessel element
Vessel elements, with perforated end walls
Pits
Tracheids

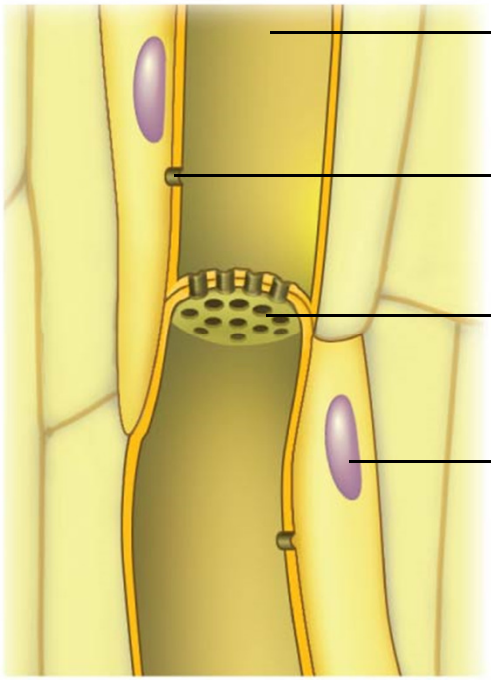
- **Sugar-conducting cells of the phloem** are alive at functional maturity
- In seedless vascular plants and gymnosperms, sugars are transported through sieve cells
- In angiosperms, sugars are transported in sieve tubes, chains of cells called **sieve-tube elements**
- **Sieve plates** are the porous end walls that allow fluid to flow between cells along the sieve tube
- Sieve-tube elements lack organelles, but each is connected via numerous plasmodesmata to a **companion cell** whose nucleus and ribosomes serve both cells
  - Reduction in cell contents enables nutrients to pass more easily through cell

Figure 28.9e



3 μm

Sieve-tube element (left) and companion cell: cross section (TEM)



Sieve-tube elements

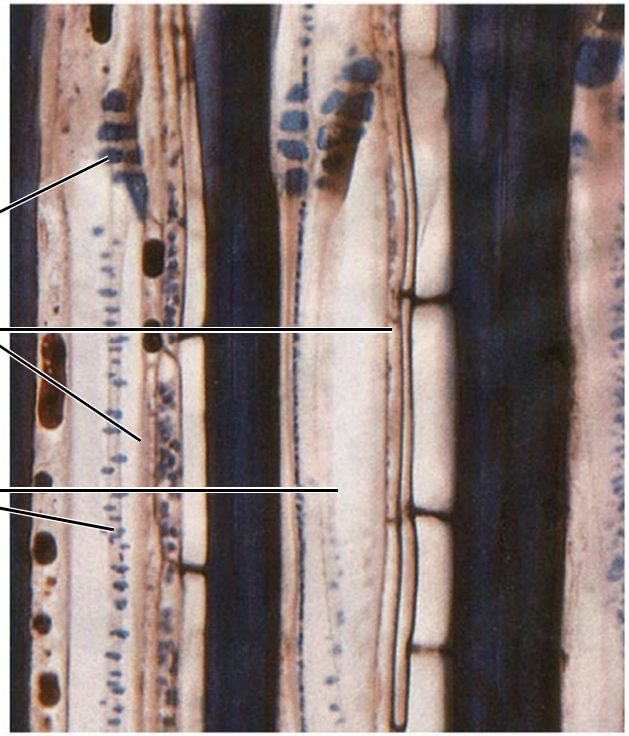
Plasmodesma

Sieve plate

Nucleus of companion cell

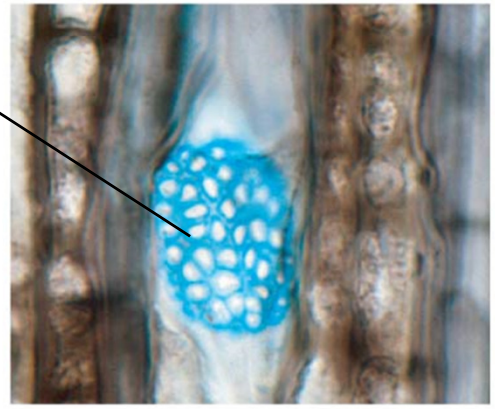
Sieve-tube elements: longitudinal view

Sieve-tube elements: longitudinal view (LM)



Sieve plate

Companion cells



30 μm

15 μm

Sieve plate with pores (LM)

Concept 28.2: Meristems generate new cells for growth and control the developmental phases and life spans of plants

- A plant can grow throughout its life
  - Called **indeterminate growth**
- Indeterminate growth is enabled by **meristems**, which are perpetually undifferentiated tissues
  - Divide when conditions permit
  - Leading to new cells that can elongate
- Most animals and some plant organs (leaves, thorns, flowers) cease to grow at a certain size
  - Called **determinate growth**

Different Meristems Produce Primary and Secondary Growth

- There are two main types of meristems
  1. **Apical meristems**
     - Located at the tips of roots and shoots and at the axillary buds of shoots
     - Enable **primary growth**
       - Growth in length
  2. **Lateral meristems**
     - Add thickness to woody plants, a process called **secondary growth**
     - There are two lateral meristems:
       - Vascular cambium and the cork cambium

- The **vascular cambium** adds layers of vascular tissue called secondary xylem (wood) and secondary phloem
- The **cork cambium** replaces the epidermis with periderm, which is thicker and tougher

- In woody plants, primary growth extends the shoots and secondary growth increases the diameter of previously formed parts

Figure 28.10

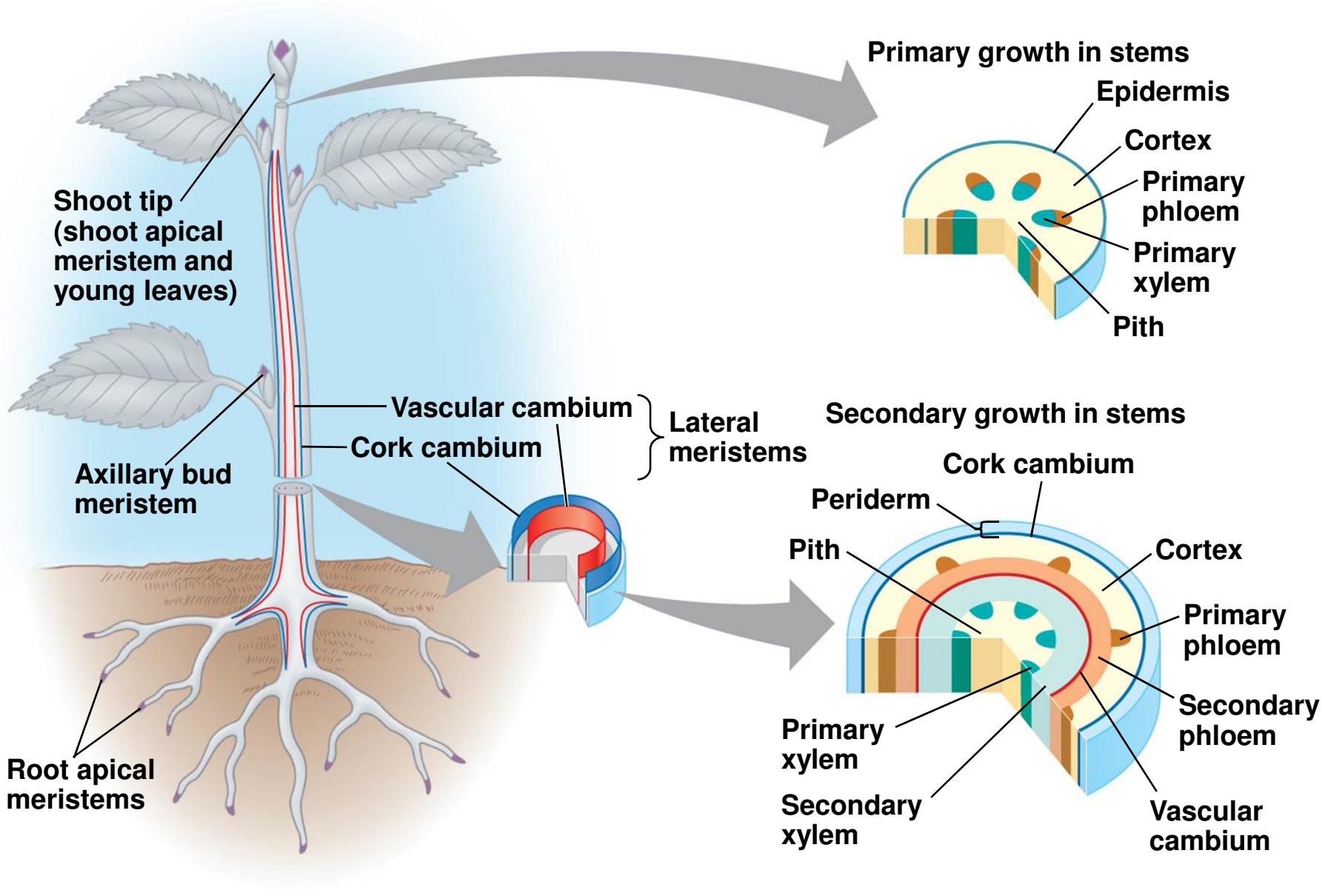
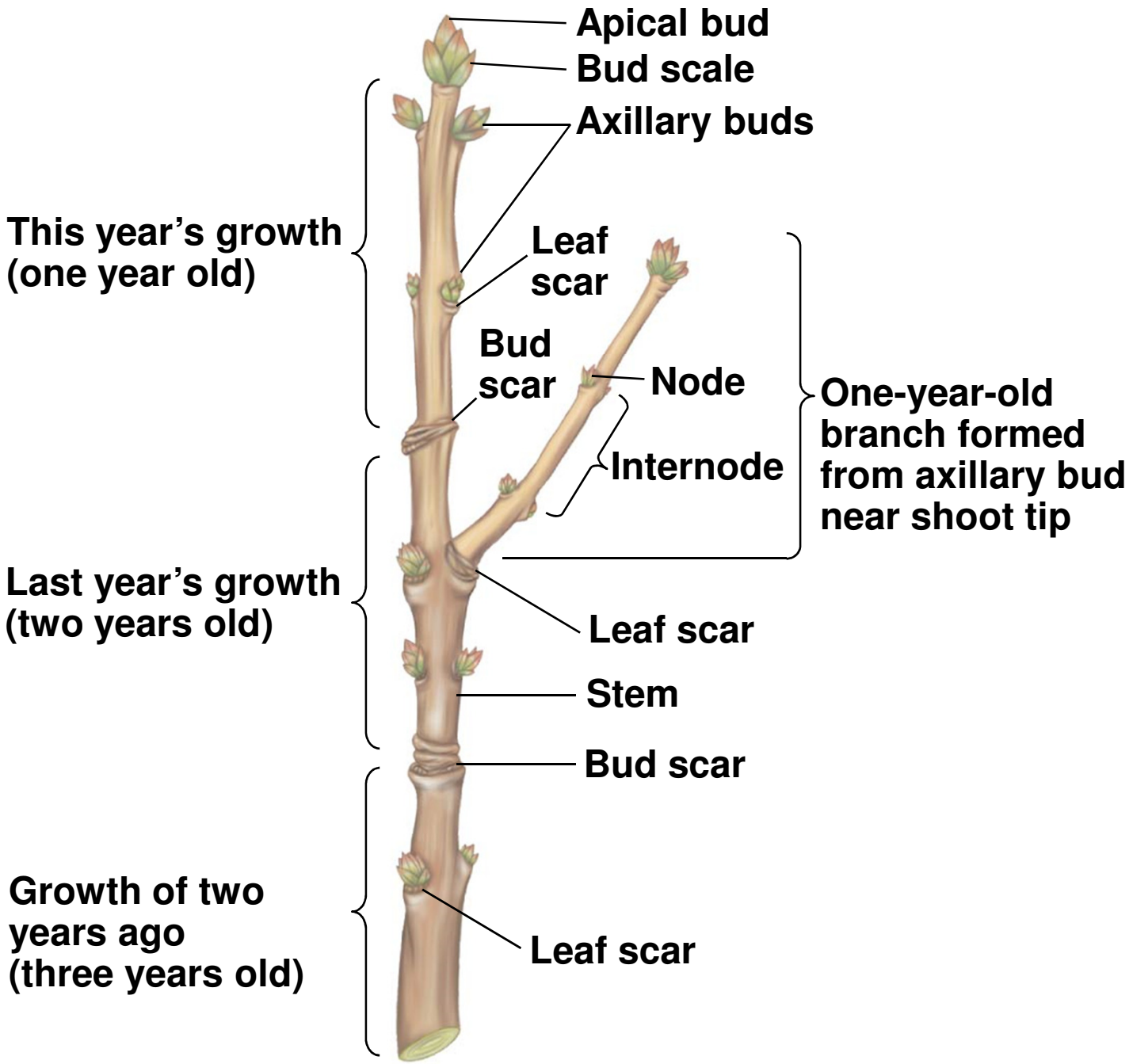

Primary growth in stems
Epidermis
Cortex
Primary phloem
Primary xylem
Pith
Shoot tip (shoot apical meristem and young leaves)
Axillary bud meristem
Vascular cambium
Cork cambium
Lateral meristems
Secondary growth in stems
Cork cambium
Periderm
Pith
Cortex
Primary phloem
Secondary phloem
Primary xylem
Secondary xylem
Vascular cambium
Root apical meristems

Figure 28.11


Apical bud
Bud scale
Axillary buds
This year's growth
(one year old)
Leaf
scar
Bud
scar
Node
Internode
One-year-old
branch formed
from axillary bud
near shoot tip
Last year's growth
(two years old)
Leaf scar
Stem
Bud scar
Growth of two
years ago
(three years old)
Leaf scar

- Cells within meristems divide frequently, generating additional cells
- Meristems give rise to
  - Initials, also called stem cells, which remain in the meristem
  - Derivatives, which become specialized in mature tissues

Meristematic Control of the Transition to Flowering and the Life Spans of Plants

- Flower formation involves a transition from vegetative growth to reproductive growth
  - Production of flowers, fruits, and seeds
- It is triggered by a combination of environmental cues and internal signals
  - Day length and hormones
- Reproductive growth is determinate
  - The production of a flower stops primary growth of that shoot

- Flowering plants can be categorized based on the timing and completeness of the switch from vegetative to reproductive growth
  - *Annuals* complete their life cycle in a year or less
  - *Biennials* require two growing seasons
  - *Perennials* live for many years

Concept 28.3: Primary growth lengthens roots and shoots

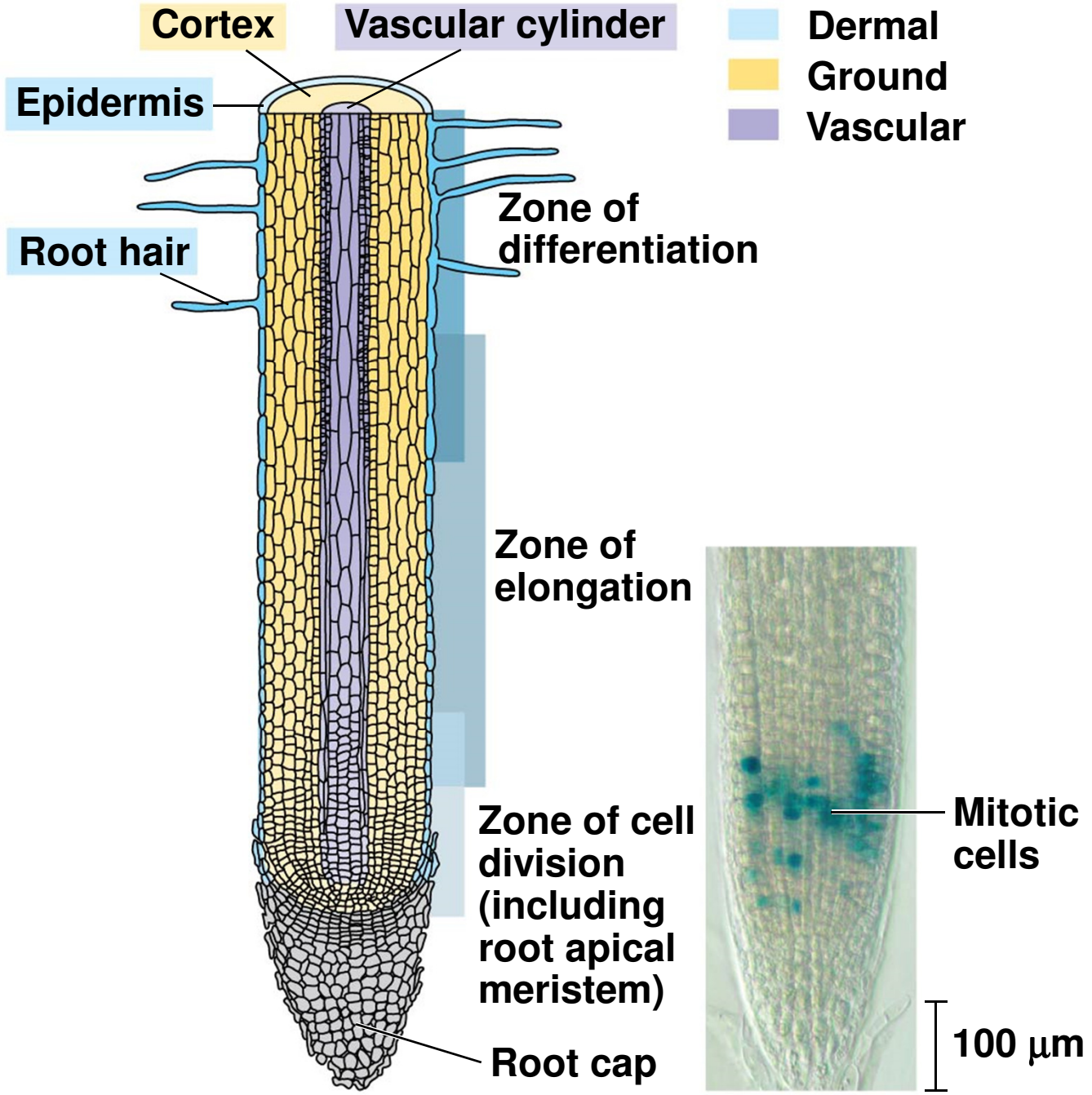
- Primary growth arises from the apical meristems and produces parts of the root and shoot systems

- The primary growth of roots produces the epidermis, ground tissue, and vascular tissue

Primary Growth of Roots

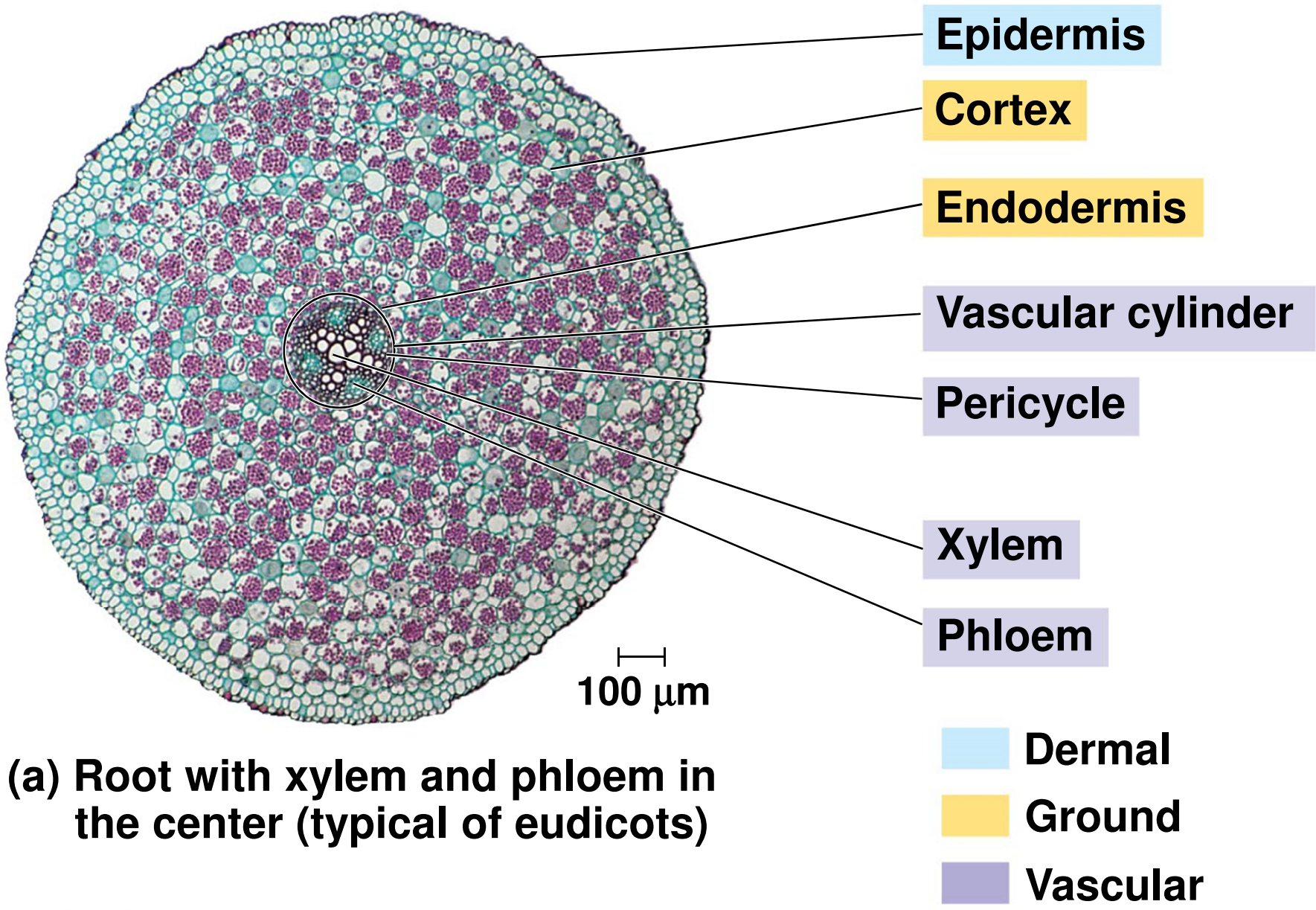
- The root tip is covered by a **root cap**
  - Protects the apical meristem as the root pushes through soil
- Growth occurs just behind the root tip, in three zones of cells
  - *Zone of cell division*
    - Includes root apical meristem and its derivatives
  - *Zone of elongation*
    - Most of the growth occurs as root cells elongate
  - *Zone of differentiation*, or maturation
    - Become distinct cell types

Figure 28.13


Cortex
Vascular cylinder
Dermal
Ground
Vascular
Epidermis
Zone of differentiation
Root hair
Zone of elongation
Zone of cell division (including root apical meristem)
Root cap
Mitotic cells
100 μm

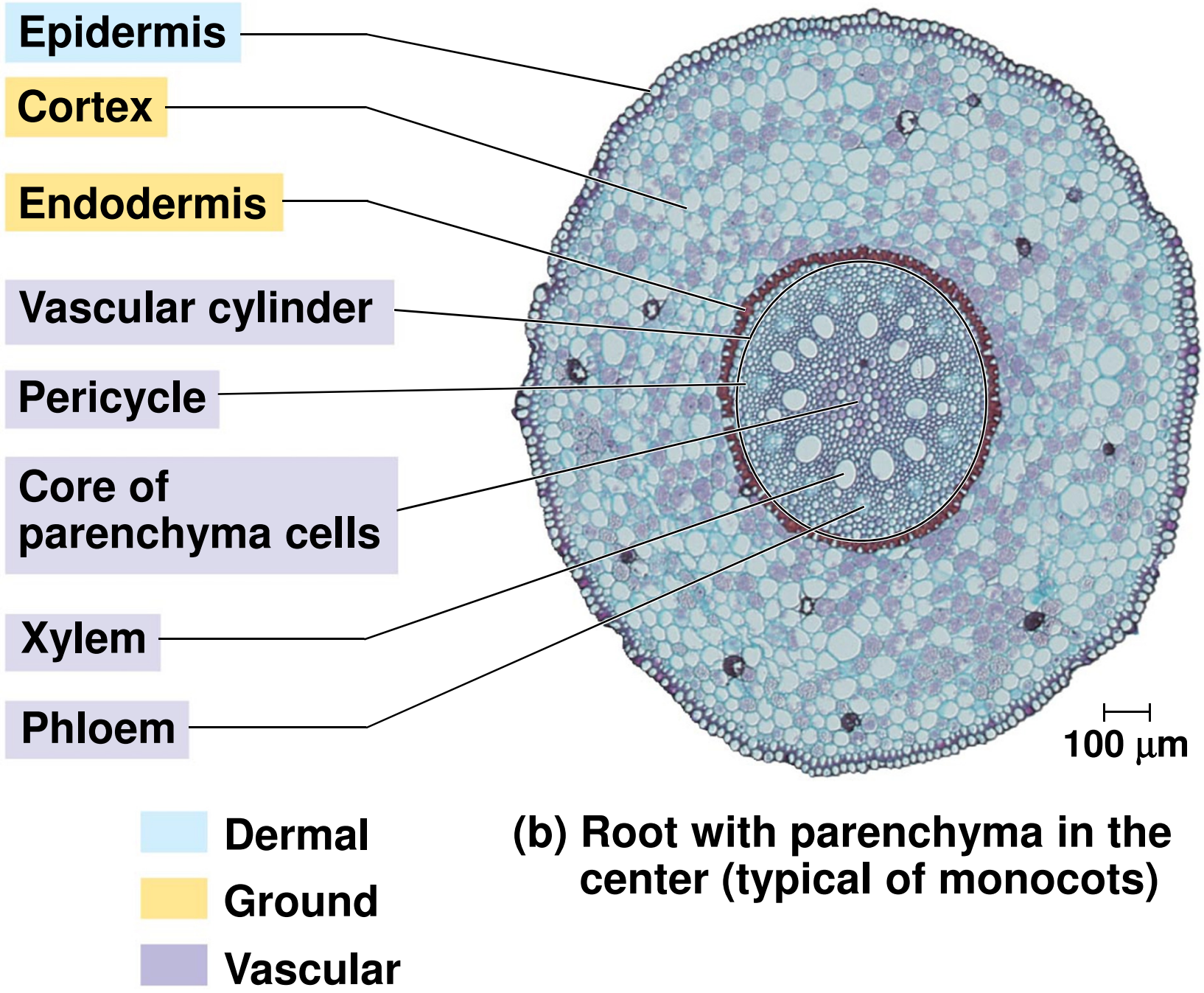
- The ground tissue, mostly parenchyma cells, fills the cortex, the region between the vascular cylinder and epidermis
  - Stores carbohydrates and transport water and salts form root hairs to center of root
- The innermost layer of the cortex is called the **endodermis**
  - Selective barrier that regulates passage of substances from the soil into the vascular cylinder
- Lateral roots arise from within the **pericycle**
  - Outermost cell layer in the vascular cylinder

Figure 28.14a



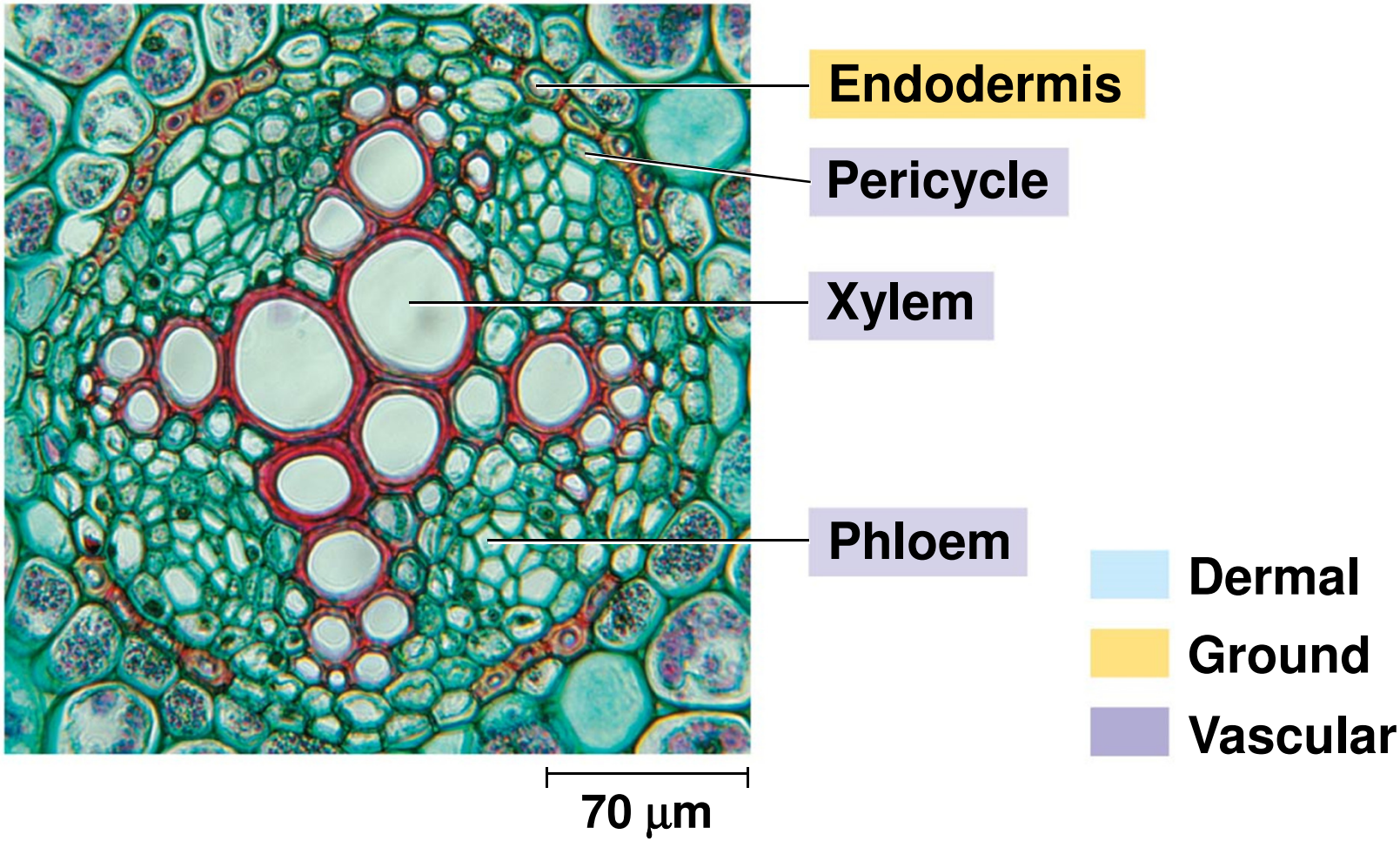
(a) Root with xylem and phloem in the center (typical of eudicots)

Figure 28.14b



(b) Root with parenchyma in the center (typical of monocots)

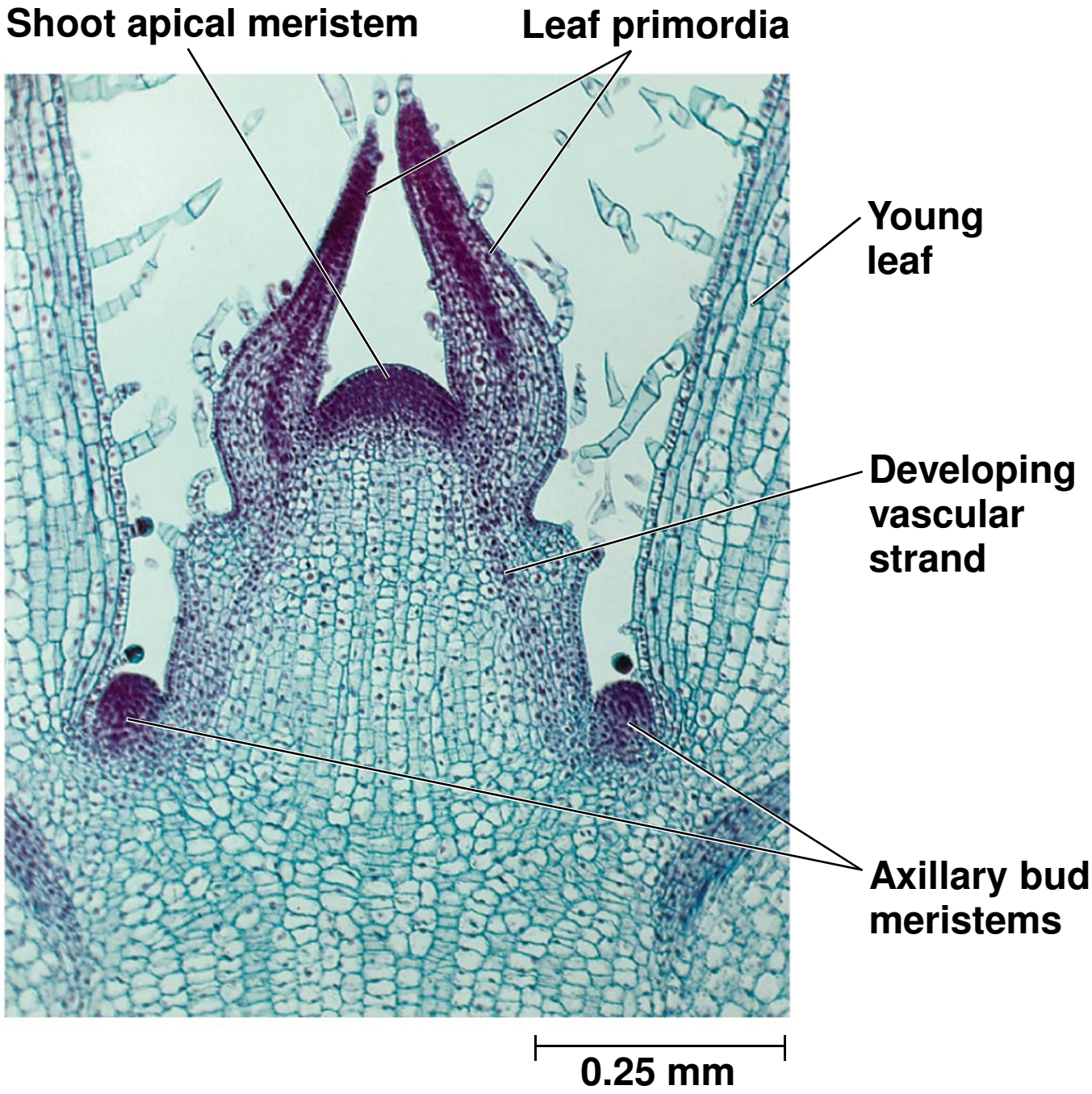
Figure 28.14c



Primary Growth of Shoots

- A shoot apical meristem is a dome-shaped mass of dividing cells at the shoot tip
- Leaves develop from **leaf primordia**
  - Projections along the sides of the apical meristem
- Shoot elongation results from lengthening of internode cells below the shoot tip

Figure 28.16


Shoot apical meristem
Leaf primordia
Young leaf
Developing vascular strand
Axillary bud meristems
0.25 mm

- Branching arises from activation of axillary buds
- Axillary buds are dormant due to **apical dominance**
  - Inhibition from an active apical bud
- Removing the apical bud stimulates growth of axillary buds
  - Resulting in more and longer branches
  - This is why pruning makes plants bushier

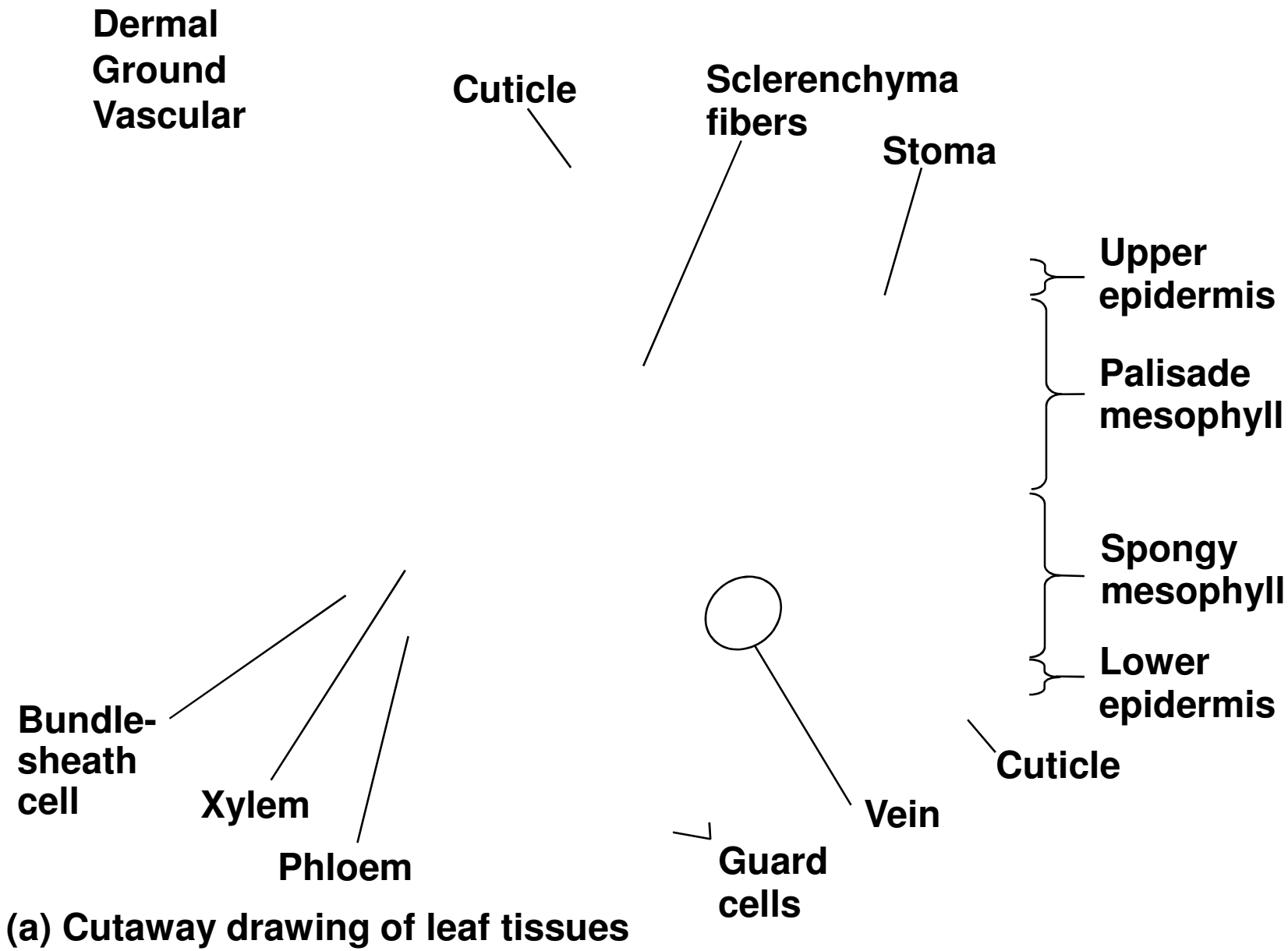
Tissue Organization of Leaves

- The epidermis in leaves is interrupted by pores called **stomata**
  - Allow CO_2 and O_2 exchange between the air and the photosynthetic cells in a leaf
  - Major avenues for evaporative water loss
- Each stomatal pore is flanked by two **guard cells**, which regulate its opening and closing

- The ground tissue in a leaf is called **mesophyll**
  - Composed of parenchyma cells sandwiched between the upper and lower epidermis
- The mesophyll of eudicots has two layers
  - The *palisade mesophyll* in the upper part of the leaf consists of elongated cells for photosynthesis
  - The *spongy mesophyll* in the lower part of the leaf consists of loosely arranged cells for gas exchange

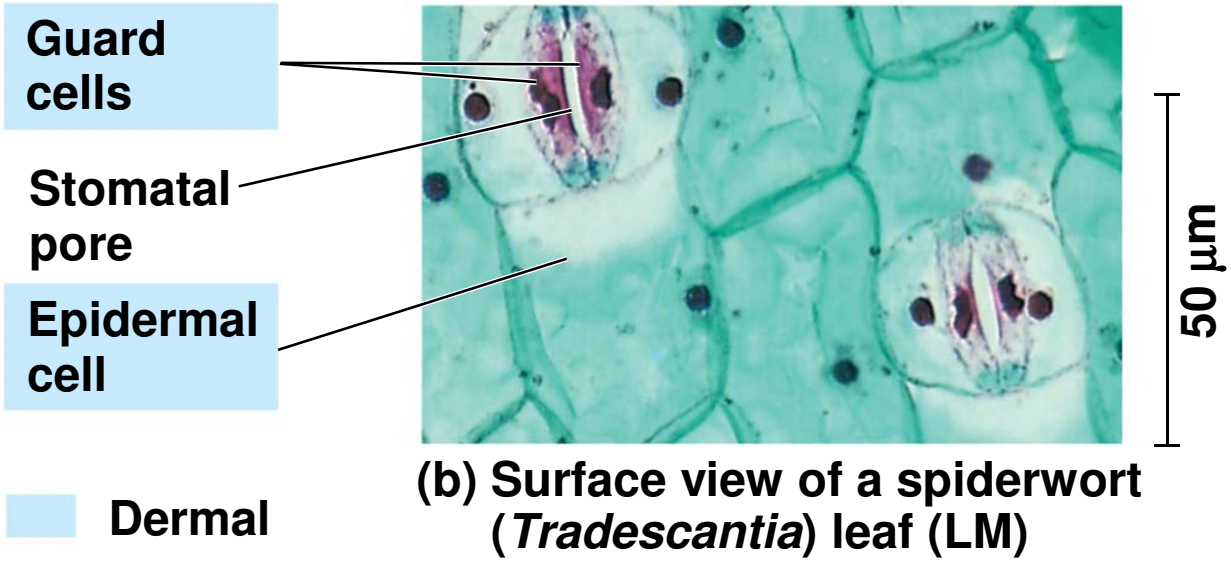
- The vascular tissue of each leaf is continuous with the vascular tissue of the stem
- Veins are the leaf's vascular bundles, which function in fluid transport and provide structure to the leaf
- Each vein in a leaf is enclosed by a protective *bundle sheath*
  - Regulates movement of substances between vascular tissue and mesophyll

Figure 28.17a



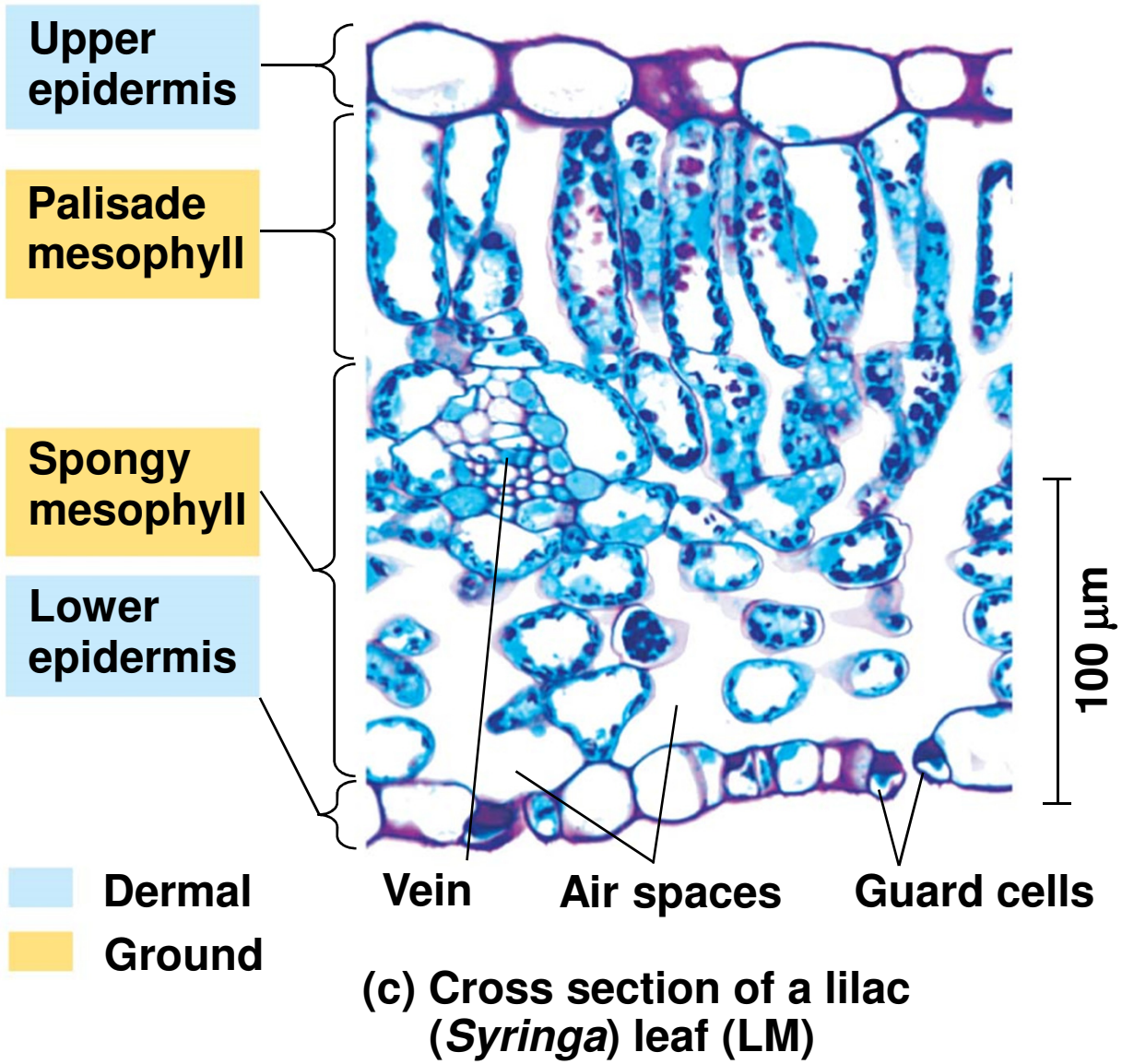
(a) Cutaway drawing of leaf tissues

Figure 28.17b



(b) Surface view of a spiderwort (*Tradescantia*) leaf (LM)

Figure 28.17c

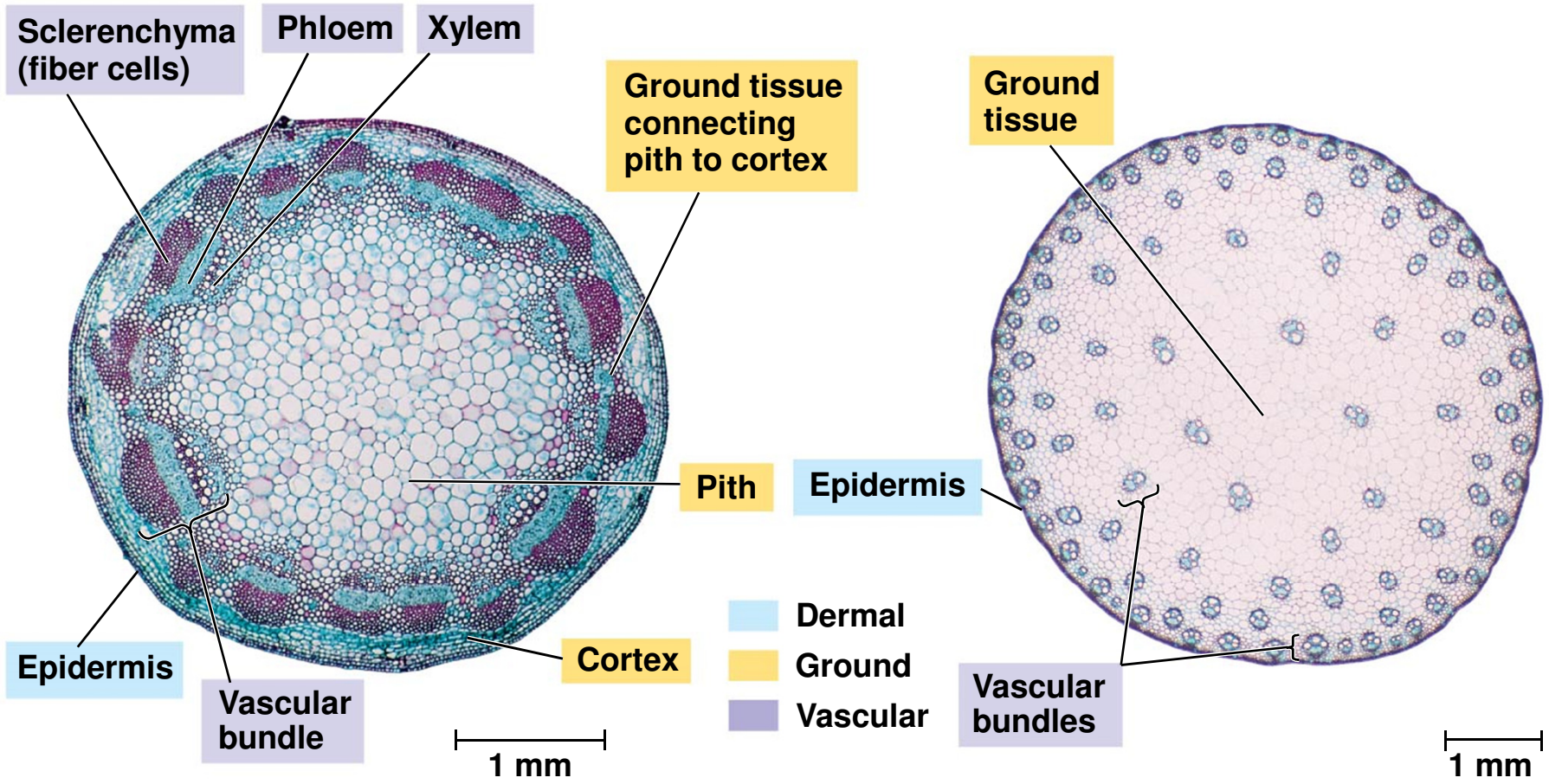


(c) Cross section of a lilac (*Syringa*) leaf (LM)

Tissue Organization of Stems

- Stems are covered in epidermis and contain vascular bundles that run the length of the stem
- Lateral shoots develop from axillary buds on the stem's surface
- In most eudicots, the vascular tissue consists of vascular bundles arranged in a ring
- In most monocot stems, the vascular bundles are scattered throughout the ground tissue, rather than forming a ring

Figure 28.18



(a) Cross section of stem with vascular bundles forming a ring (typical of eudicots)

(b) Cross section of stem with scattered vascular bundles (typical of monocots)

Concept 28.4: Secondary growth increases the diameter of stems and roots in woody plants

- Secondary growth is characteristic of gymnosperms and many eudicots, but not monocots
- Secondary growth occurs in stems and roots of woody plants but rarely in leaves
- In woody plants, primary growth and secondary growth occur simultaneously but in different locations

- The secondary plant body consists of the tissues produced by the
  - Vascular cambium
    - Adds secondary xylem (wood) and secondary phloem
    - Increases vascular flow and support for shoots
  - Cork cambium
    - Produces tough, thick covering of waxy cells
      - Protect stem from water loss and pests

Figure 28.19a-3

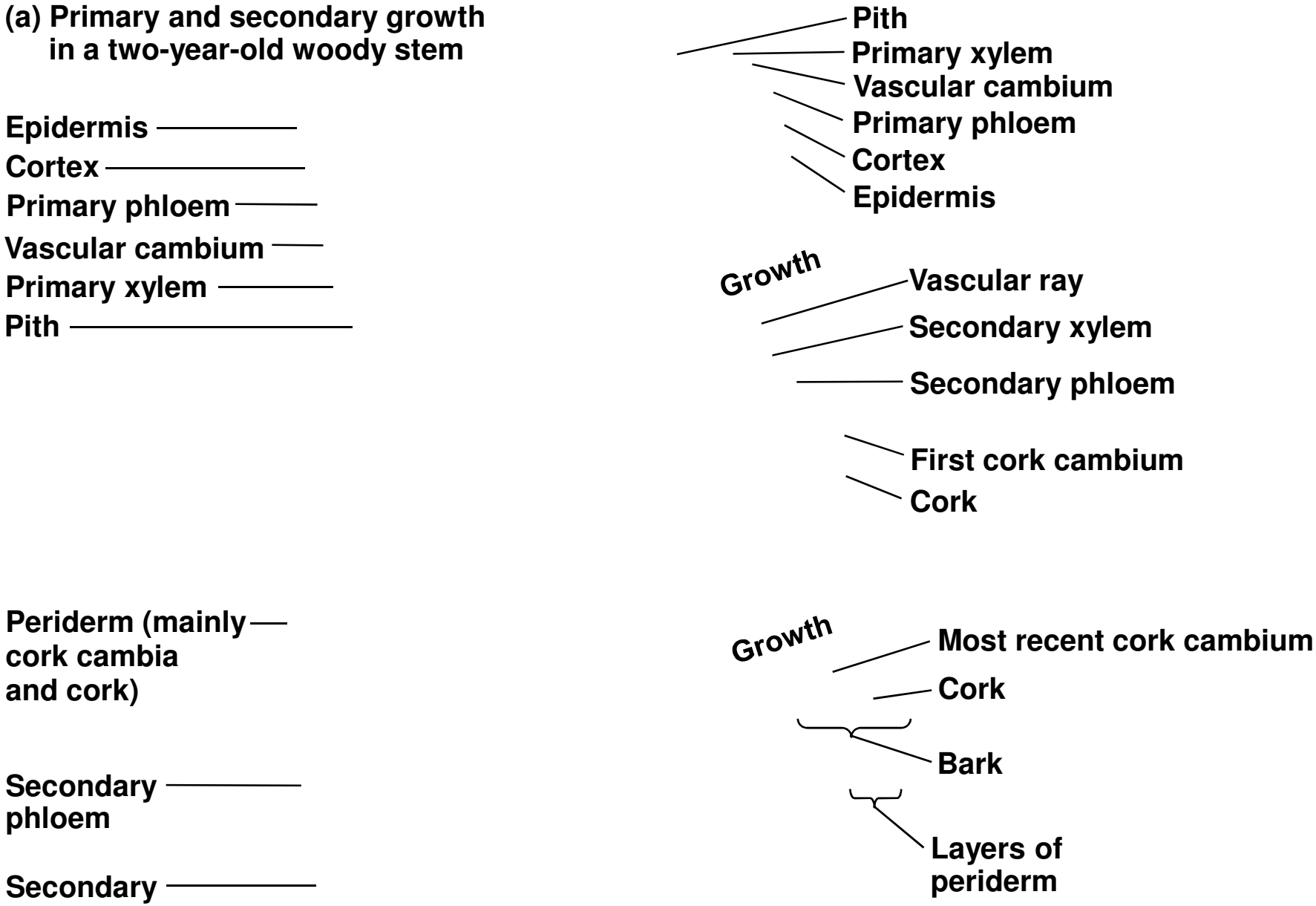
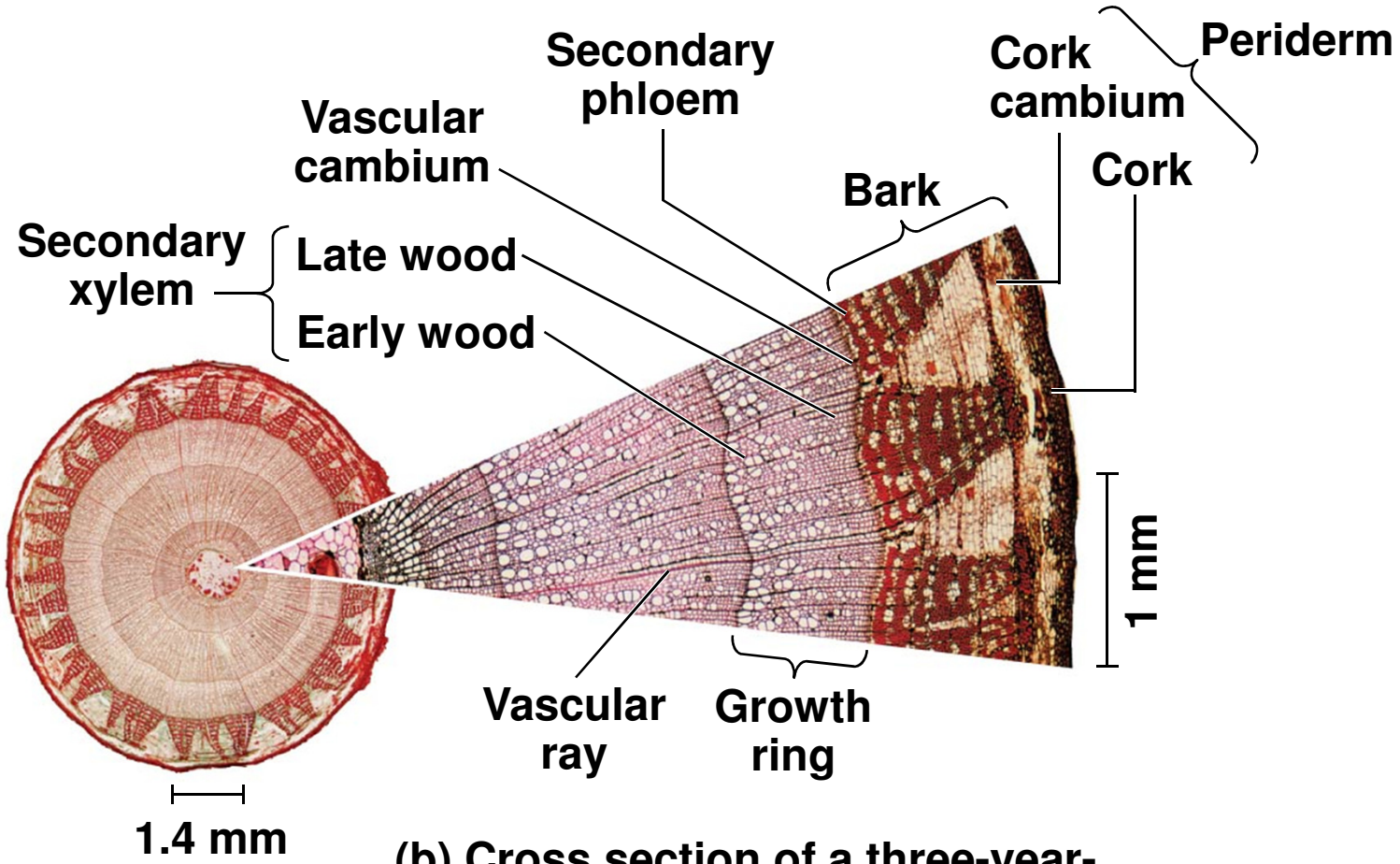


Figure 28.19b

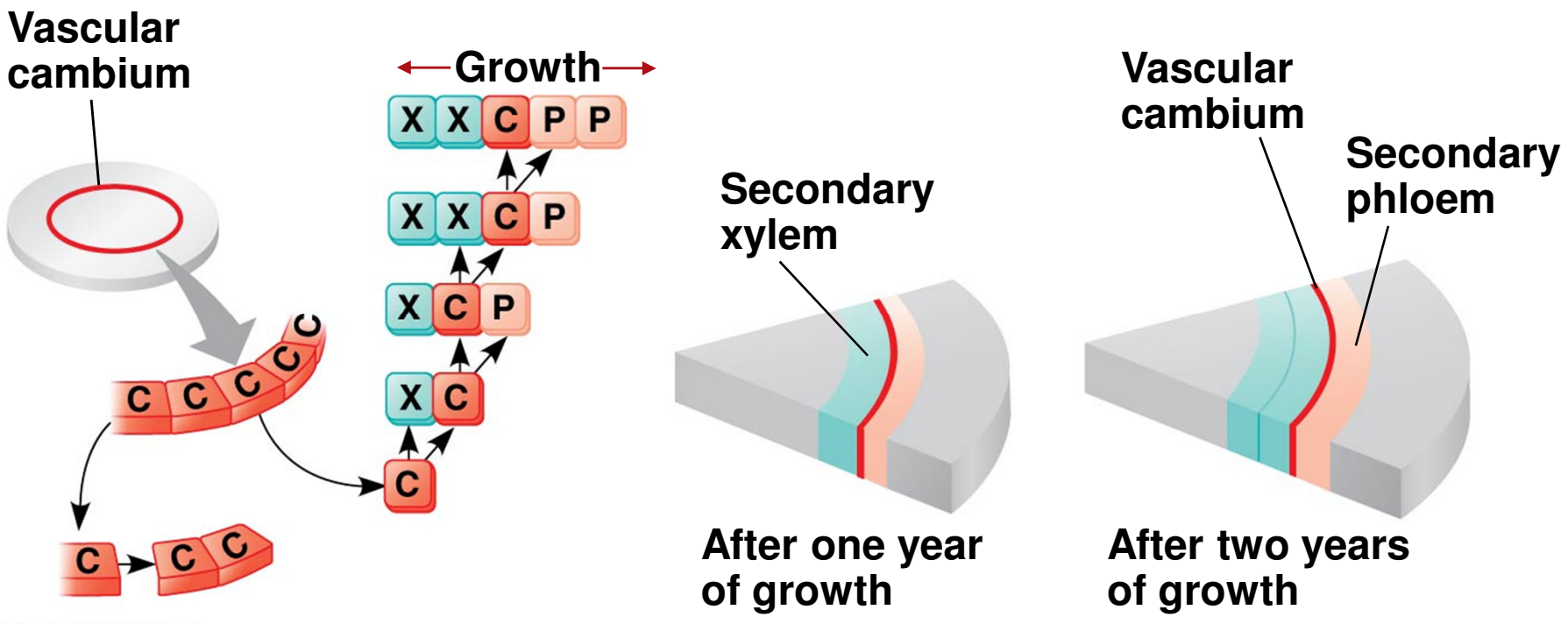


(b) Cross section of a three-year-old *Tilia* (linden) stem (LM)

The Vascular Cambium and Secondary Vascular Tissue

- The vascular cambium produces secondary vascular tissue
  - Adds secondary xylem to the inside and secondary phloem to the outside
- Secondary xylem accumulates as wood and consists of tracheids, vessel elements (only in angiosperms), and fibers

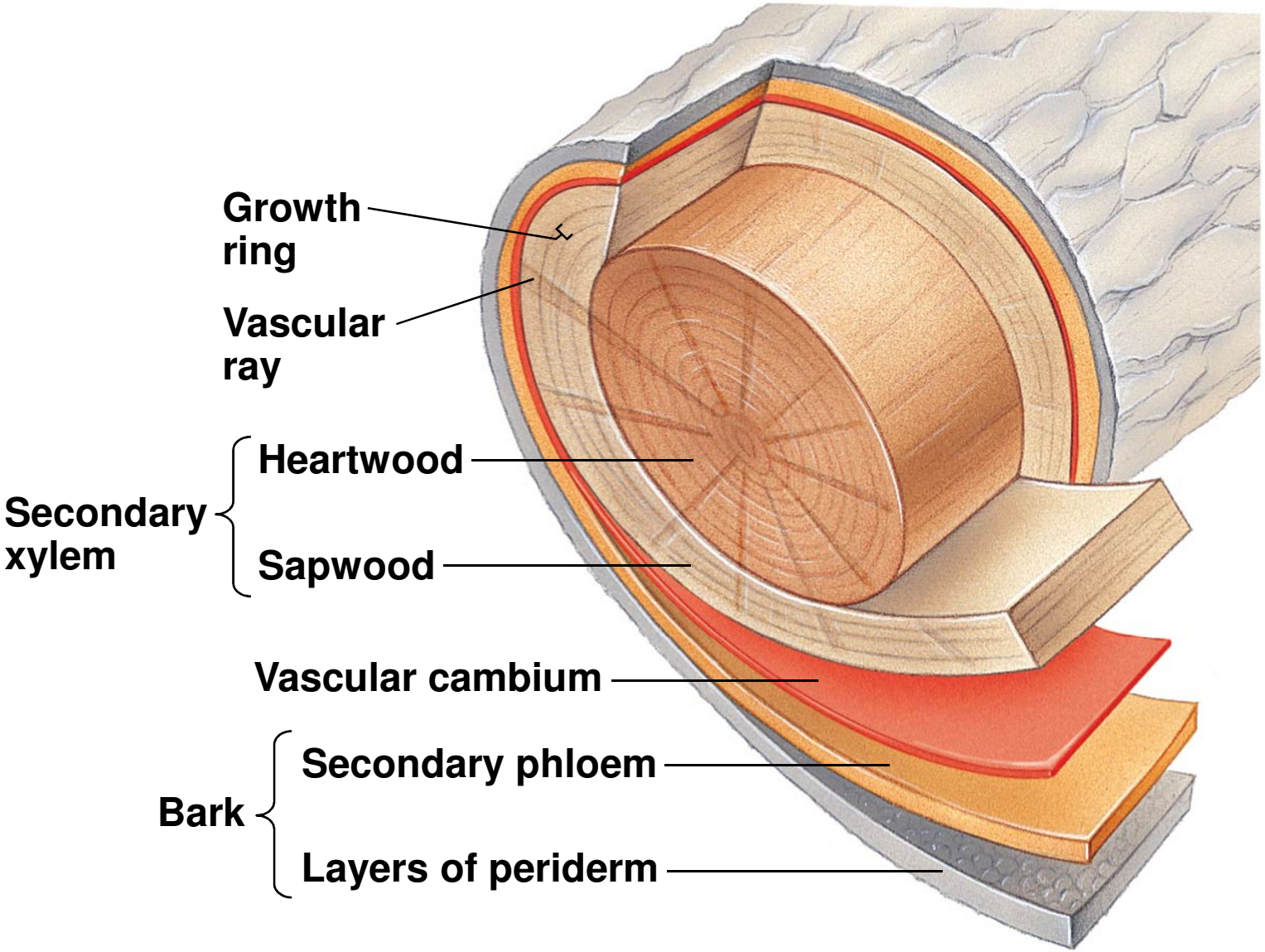
Figure 28.20


Vascular cambium
Growth
X X C P P
X X C P
X C P
X C
C
C C C C C
C C C
Secondary xylem
After one year of growth
Vascular cambium
Secondary phloem
After two years of growth

- Early wood, formed in the spring, has thin cell walls to maximize water delivery
- Late wood, formed in late summer, has thick-walled cells and contributes more to stem support
- In temperate regions, the vascular cambium of perennials is inactive through the winter
- Tree rings are visible where late and early wood meet and can be used to estimate a tree's age
  - *Dendrochronology* is the analysis of tree ring growth patterns and can be used to study past climate change

- As a tree or woody shrub ages, the older layers of secondary xylem, the *heartwood*, no longer transport water and minerals (sap)
- The outer layers, known as *sapwood*, still transport materials through the xylem
- Only young secondary phloem transports sugar
  - Older secondary phloem sloughs off and does not accumulate

Figure 28.21


Growth ring
Vascular ray
Secondary xylem
Heartwood
Sapwood
Vascular cambium
Bark
Secondary phloem
Layers of periderm

The Cork Cambium and the Production of Periderm

- The cork cambium gives rise to *cork cells* that accumulate to the exterior of the cork cambium
- Cork cells deposit waxy *suberin* in their walls and then die
- Periderm consists of the cork cambium and the cork cells it produces
  - Periderm functions as a protective barrier, impermeable to water and gasses, unlike the epidermis

- **Bark** consists of all the tissues external to the vascular cambium, including secondary phloem and periderm
- **Lenticels** in the periderm allow for gas exchange between living stem or root cells and the outside air

- Remember, the whole plant functions as an integrated organism